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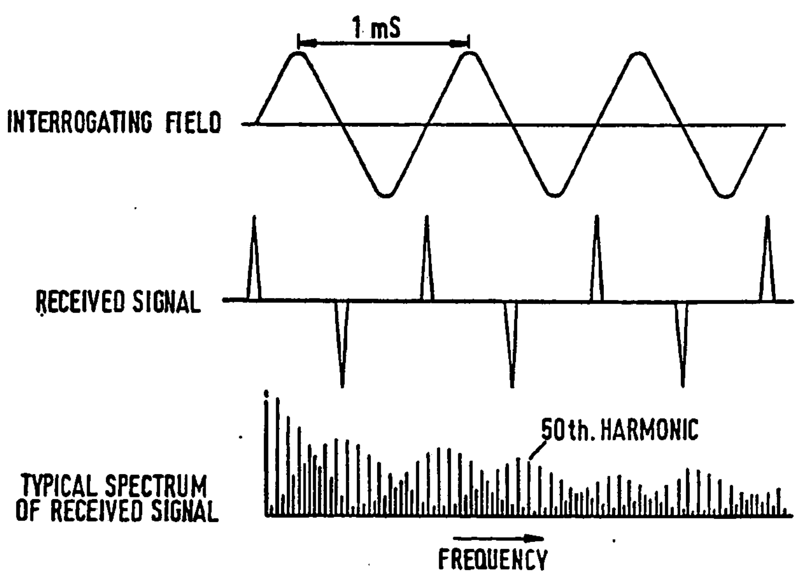

Signal Produced by Interrogating with 1 KHz Field

(57) Abstract

A method for installation and subsequent location of a concealed object such as an underground cable or pipe comprises locating on or near the object a detection element formed of a ferromagnetic alloy having a high permeability and low coercivity for providing a characteristic magnetic response to an interrogating magnetic field whereby the object can be subsequently located. A detecting apparatus produces an interrogating magnetic field, and incorporates means for detecting a returned signal in accordance with the magnetic response of the element.

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Installation and detection method for concealed objects

This invention relates to methods for installing and subsequently detecting concealed objects, in particular service installations such as pipes, cable ducts, fibre optic cables etc which are located underground or under water.

There is a need to be able to detect a concealed service installation for the purposes of carrying out repairs to the installation, and also to avoid inadvertant damage to the installation as a result of roadworks, excavations etc unconnected with the installation concerned. The need is enhanced by the ever-increasing density of service installations.

Whilst, previously, underground electric cables have been detected by their electromagnetic radiation, optical fibre communications installations, which are becoming increasingly common, provide no natural emission which can be remotely detected. In the case of metal pipes, known underground metal detecting techniques have been used, but these generally provide poor discrimination and are of course inapplicable to plastic and concrete pipes and ducts, for example.

It has also been proposed to provide resonant inductive/capacitive circuits buried at intervals close to an installation for use as dectectors. Such units provide a resonant response to a driving electromagnetic field from detecting units similar to conventional metal detectors. Such "active" units are however relatively costly so that the installation interval has, in practice, been large (typically 100m) and the response obtained can be affected by nearby metal objects.

Viewed from one aspect the invention provides a method of installing an underground or underwater

object which comprises locating on or near the object a detection element formed of a ferromagnetic alloy having a high permeability and low coercivity for providing a characteristic magnetic response to an interrogating magnetic field so that the object can be subsequently located.

The invention extends to a method of locating an underground or underwater object which has been installed in this way, comprising generating a magnetic field to which the detection element is exposed, and detecting a magnetic response of said detection element to determine the location of the object.

Viewed from a further aspect the invention provides an underground or underwater object in combination with a detection element formed of a ferromagnetic alloy having a high permeability and low coercivity and providing a characteristic magnetic response to a detection magnetic field to produce a signal whereby the installation can be located.

The invention is particularly applicable to underground or submarine service installations, such as gas and water pipes, cable ducts and fibre optics cables in respect of which an inexpensive and effective detection system may be provided.

A portable detecting apparatus can be provided to generate suitable magnetic fields with which to interrogate the detection element, and may include a receiver system which responds to particular magnetic responses from the element.

In accordance with the invention, the alloy of which the detection element is formed has a high intrinsic permeability, typically greater than 10,000 and a low coercive force, typically less than 20 Amps/metre. Particularly suitable alloys providing appropriate magnetic characteristics are amorphous alloys i.e. so-called metallic glasses. Suitable alloys are commercially available from Unitica of Japan and Vacuumschmeltz of Germany.

It will be appreciated that, since materials having comparable magnetic characteristics to those outlined above are unlikely to be found naturally in the proximity of an underground or underwater installation, the method in accordance with the invention is unlikely to be affected by other nearby underground objects.

It is desirable that the detection element should be formed in such a way that the apparent permeability is not seriously degraded by demagnetisation effects. Preferably, therefore, the element should be in the form of a thin strip or wire, or a thin film. The wire, strip or film is preferably in the form of discrete segments. In the case of a service installation it is envisaged that a plurality of detection elements would be spaced along the installation. Typical dimensions for the elements might be 40 mm x 1 mm x 0.03 mm for a thin strip, or 40 mm x 40 mm x 0.001 mm for a film.

In the case of service installations such as pipes and cables, detection elements are preferably attached at frequent intervals such as one every one or two metres. The elements can be incorporated into adhesive labels for attachment to the service installation at the time of installation, or alternatively could be incorporated into an installation at the time of its manufacture e.g. by being embedded into a pipe or fibre optics cable. It is also envisaged that the detection elements could be located separately from though near the serice installation. For example, in the case of an underground power cable it is known to provide a physical warning means in the form of a marker cable buried somewhat above the pipe, and detection elements in accordance with the invention could be carried by such cable.

In one form, a detection apparatus generates an oscillating field in the detection region of one or more frequencies. The non-linear magnetic response

of the detection element gives rise to reradiated harmonics of the drive field which are detected by a sensor unit. These harmonics are highly distinctive of the detection element and provide high discrimination against significant amounts of other metals. Typically a detector system is capable of detecting down to $0.25mm^3$ of material in a volume of $2m^3$.

A detection apparatus for use in accordance with the present invention comprises, in one form, a drive coil or coils which interrogate the ground underneath the apparatus with one or more frequency signals and detects the harmonic or intermodulation products reradiated by the detection element formed of high permeability, low coercivity alloy associated with the object to be detected. Such apparatus can be packaged to resemble a conventional metal detector or in some other suitable format.

Whilst the present invention is particularly applicable to the location of buried and submarine service installations, the method may be applied to other concealed objects which require subsequent detection.

A preferred system for implementing the method in accordance with the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 illustrates the idealised magnetic response of a high permeability, low coercive force ferromagnetic alloy from which detection elements in accordance with the invention are formed;

Figure 2 illustrates schematically an interrogating magnetic field together with the response received from an element in accordance with the invention, and

Figure 3 illustrates alternative embodiments of a detection apparatus.

As shown in Figure 1, a high permeability, low coercive force alloy such as an amorphous metal

alloy i.e. a metallic glass provides a non-linear magnetic response. In one embodiment of detection apparatus, an alternating magnetic field in the detection region at a frequency in the order of 1 KHz interrogates a detection element in accordance with the invention, the non-linear magnetic response of which gives rise to re-radiated harmonics of the interrogating frequency, as shown in Figure 2, and these can be detected by a tuned receiving system. The harmonics produced extend to very high orders and are very distinctive of the alloy from which the detection element is formed. This provides high discrimination against significant amounts of other metal which typically only produce low order harmonics, and thus, in accordance with the invention, buried service installations, for example, can be detected with high accuracy. A preferred detector system is capable of detecting down to 0.25 mm^2 of material in a volume of 2 m^2.

Detection apparatus for use in a method in accordance with the present invention can operate on similar principles to known security devices used in retail outlets to detect shop-lifting. In one form a drive coil or coils is arranged to interrogate beneath the detector with one or more alternating magnetic fields, and detects one or more harmonic or intermodulation products re-radiated by the ferro-magnetic detection element. Block diagrams of two known detector systems suitable for use in the present invention are illustrated in Figure 3. The operation of such systems will be known to those with the relevant skill, and will not be described in further detail. Whilst previously such apparatus have been incorporated, for example, at the exit points of shops to detect unauthorised removal of goods, in accordance with the invention the apparatus is preferably packaged to resemble a conventional metal detector, or in some other suitable format. It will be appreciated

that generally, in contrast to the use of such apparatus as security devices, the detection element in accordance with the invention will be fixedly located, typically in an underground environment, whilst the detection apparatus is mobile.

The size and shape of the detection elements, together with the size and dimensions of the detector coil, and the interrogating field amplitude and frequency etc may all vary. As an indication, however, a detection element in the form of a thin strip approximately 40 mm long can be detected underground at a depth of the order of the diameter of the detector coil with a resolution of the order of the coil radius.

Claims:

1. A method of installing an underground or underwater object which comprises locating on or near the object a detection element formed of a ferromagnetic alloy having a high permeability and low coercivity for providing a characteristic magnetic response to an interrogating magnetic field whereby the object can be subsequently located.

2. A method of detecting an underground or underwater object which has been installed by a method in accordance with claim 1, comprising generating a magnetic field to which the detection element is exposed, and detecting a magnetic response of said detection element to determine the location of the object.

3. A method as claimed in claim 1 or 2 wherein the object comprises a service installation.

4. A method as claimed in claim 3 wherein the service installation comprises an underground duct, pipe or cable.

5. A method as claimed in any preceding claim wherein the detection element is in the form of a thin sheet, strip or wire of said alloy.

6. A method as claimed in claim 5 wherein a plurality of said elements in the form of discrete lengths of alloy sheet, strip or wire are spaced along the object.

7. A method as claimed in any preceding claim wherein the alloy from which the detection element is formed has an intrinisic permeability greater than 10,000 and a coercive force of less than 20 Amps/metre.

8. A method as claimed in claim 7 wherein the detection element is formed of an amorphous metal alloy.

9. A method as claimed in any preceding claim in which detection elements comprise or are incorporated in adhesive labels.

10. An underground or underwater object in combination with a detection element formed of a ferromagnetic alloy having a high permeability and low coercivity and providing a characteristic magnetic response to a detection magnetic field to produce a signal whereby the installation can be detected.

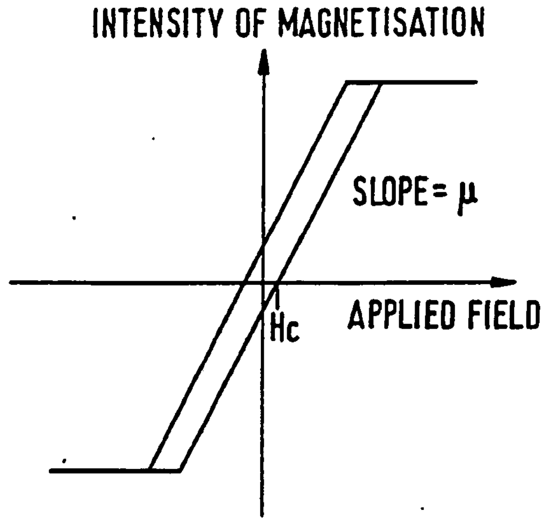


FIG. 1 Idealised Magnetic Response of Marker

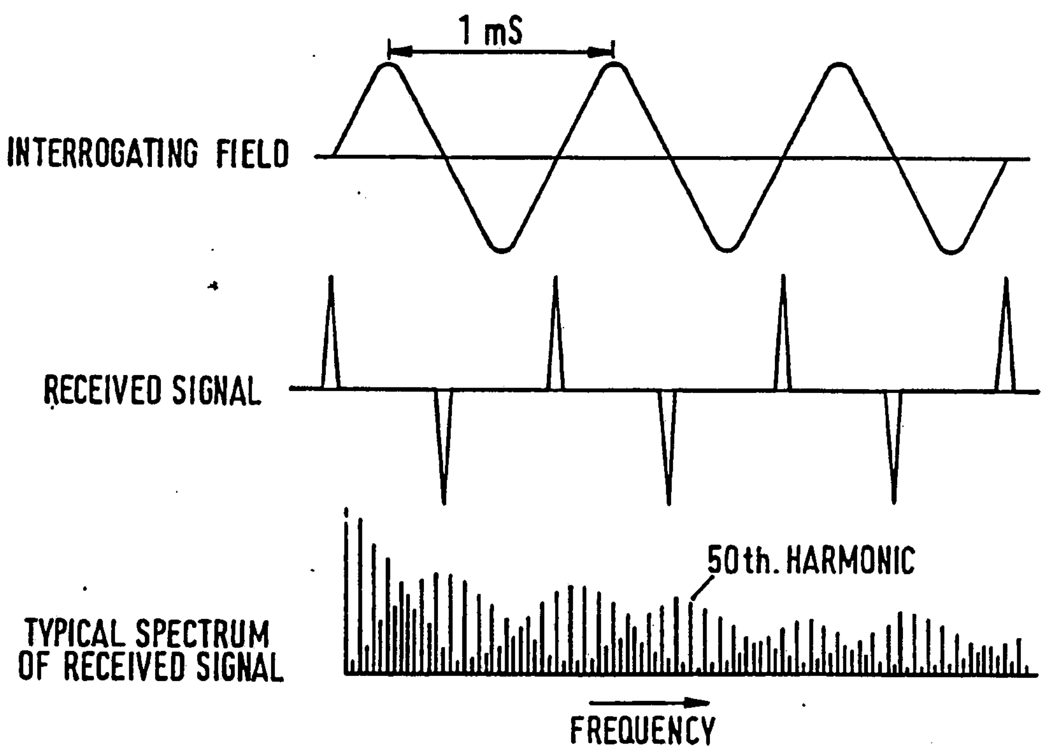
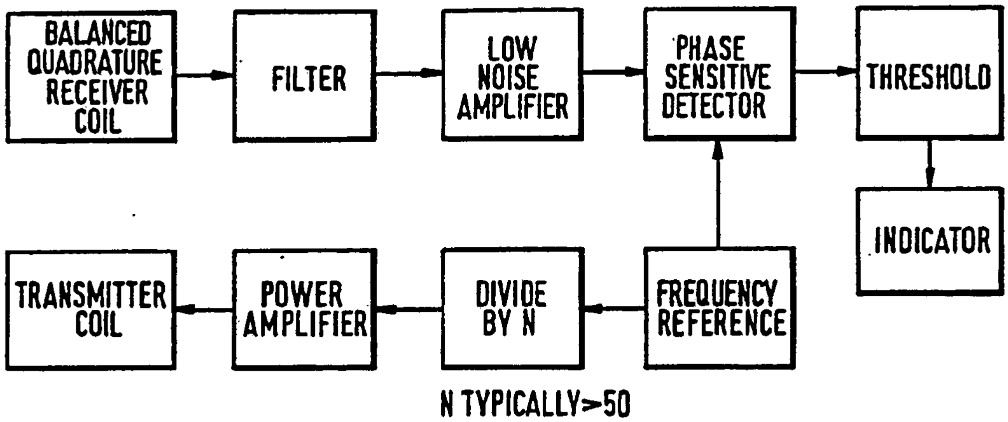
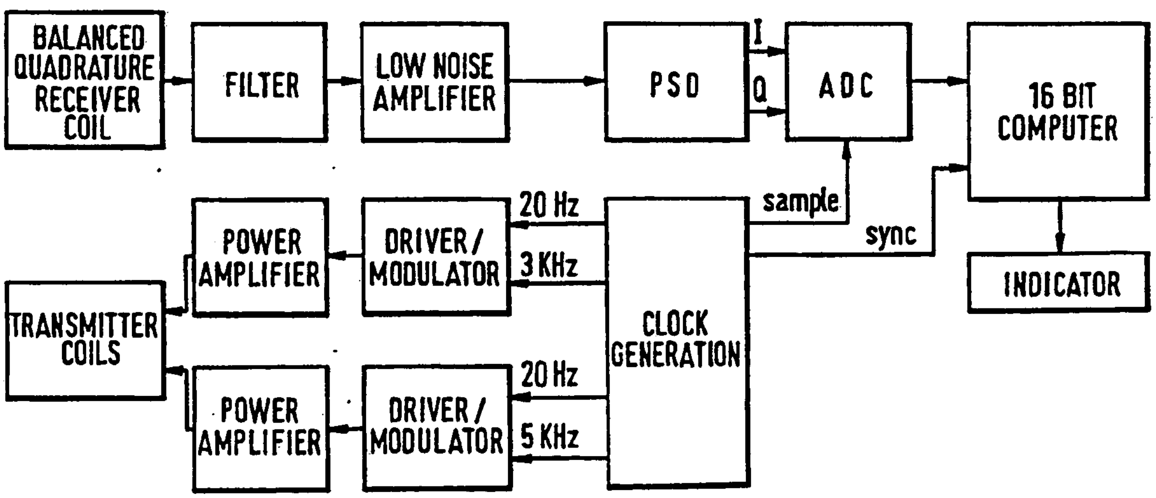


FIG. 2 Signal Produced by Interrogating with 1 KHz Field



Simple single frequency narrowband detection system.

FIG. 3 DETECTION SYSTEMS



3 frequency detection system with improved discrimination.

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 89/00031

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC4: G 01 V 3/08, H 02 G 9/00

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC4	G 01 V, H 02 G, G 01 S, G 08 B

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [*]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
Y	US, A, 4660025 (F B HUMPHREY) 21 April 1987, see the whole document --	1,2,5-8, 10
Y	US, A, 4581524 (E B HOEKMAN ET AL) 8 April 1986, see column 2, line 20 - column 3, line 11; figures 1,2 --	1-6,8-10
Y	US, A, 4553136 (P M ANDERSON, III ET AL) 12 November 1985, see the whole document --	1-6,8-10
Y	DE, A1, 3106661 (KABEL- UND METALLWERKE GUTEHOFFNUNGSHÜTTE AG) 9 September 1982, see the whole document --	1-10

* Special categories of cited documents: [10]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
21st April 1989	27 APR 1989
International Searching Authority	**Signature of Authorized Officer**
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III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

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Y	EP, A2, 224834 (REEF INDUSTRIES, INC.) 10 June 1987, see the whole document --	1-10

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. PCT/GB 89/00031

SA 26404

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